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THE ROLE OF THE PHYSICAL SCIENCES IN ELECTRICAL-ELECTRONIC TECHNOLOGY. PROGRESS REPORT.

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TO DETERMINE THE RELATIVE IMPORTANCE OF CHEMISTRY AND PHYSICS FOR INSTRUCTION IN ELECTRICAL AND ELECTRONIC TECHNOLOGY, 51 TECHNICAL WORKERS, 51 JUNIOR COLLEGE INSTRUCTORS, AND 11 EXPERTS RATED 240 SCIENTIFIC PRINCIPLES AS TO THEIR VALUE IN A TECHNICIAN'S WORK. THE THREE GROUPS AGREED ON THE RANK ORDER OF 15 TOPICS--(1) CURRENT ELECTRICITY, (2) STATIC ELECTRICITY, (3) MAGNETISM, (4) ATOMIC ENERGY AND RADIATION, (5) SOUND, (6) THE MECHANICS OF SOLIDS, (7) THE STRUCTURE OF MATTER, (8) LIGHT, (9) HEAT, (10) THE MECHANICS OF GASES, (11) THE MECHANICS OF LIQUIDS, (12) THE CHEMICAL NATURE OF MATTER, (13) THE GENERAL PROPERTIES OF ENERGY AND MATTER, (14) IONS IN SOLUTIONS, AND (15) SOLUTIONS AND COLLOIDS. THE APPENDIX GIVES THE RANK ORDER OF MAJOR TOPICS AND OF ITEMS WITHIN THOSE TOPICS AND THE RANK ORDER OF ITEMS WITHIN THE WHOLE LIST. IT WAS CONCLUDED THAT A RANKING OF TOPICS FOR GENERAL EDUCATION WAS NOT SUITABLE FOR SPECIFIC OCCUPATIONAL COURSE PLANNING. (EM)

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The Role of the Physical Sciences in Electrical-Electronic Technology

PROGRESS REPORT

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DIVISION OF VOCATIONAL EDUCATION
UNIVERSITY OF CALIFORNIA, LOS ANGELES
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The Role of the Physical Sciences in Electrical-Electronic Technology

(Progress Report)

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Foreword

The study of the role of the physical sciences in electrical-electronic technology was started during the school year 1961-62. The major portion of the research was completed during the period allocated for the study, but the time was not available to pursue supplementary research which was found to be essential for a proper review of the role of the physical sciences in electrical-electronic technology. Therefore this report must of necessity be considered as a progress report on the general topic. It is anticipated that the research will continue in order to get to the essential items of information upon which decisions concerning the physical science programs for junior colleges must be based.

During the year 1961-62 Dr. William J. Schill, then a Research Assistant in the Division of Vocational Education, was the principal investigator. Since 1962 Dr. Schill has been located at the University of Illinois, where he holds the rank of Assistant Professor of Industrial Education and where he is pursuing significant research in the general technical area.

Mr. George Peranteau, Research Assistant in the Division of Vocational Education, has been primarily concerned with the organization and presentation of this progress report.

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Introduction

The study of the role of mathematics in electrical-electronic technology[1] brought clearly into view the need for a similar study of the role of the physical sciences. The immediate problem was to determine what physical science concepts technical workers used in their work. To answer this question is to indicate the answer to the related question, what physical science concepts ought to be taught in electrical-electronic programs? The latter question is of deep interest to the public unior colleges in California.

To study the role of the physical sciences, departures had to be made from the sample selection procedures used in the previous report. Instead of taking a representative sample of all technical workers, the sample was restricted to those technical workers who had had a substantial amount of formal study of the physical sciences (defined for this research to include physics and inorganic chemistry). It seemed imperative that the technical worker should have studied various phases of the physical science concepts or principles basic to his work, for he had to be aware of such principles in order to be able to rate them as relevant or not. The worker lacking this background could conceivably perform his job without being aware of the principles behind his actions.

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[1] Melvin L. Barlow and William J. Schill, The Role of Mathematics in Electrical-Electronic Technology, Division of Vocational Education, University of California, Los Angeles, 1962.

It was conceived as a general criterion that all participants in the study should have as broad a background as possible and should otherwise be as nearly representative of the industry as possible. The same criteria were applied to instructors who participated in the study. In both cases technical workers and instructors had, in a sense, to be overqualified for their tasks, with an adequate balance between theory and practice, and yet still able to make a realistic estimate of the practical worth of physical science principles.

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The Role of the Physical Sciences in Electrical-Electronic Technology

(Progress Report)

The Problem and Purpose of the Study

The on-the-job activities of technical workers in electrical and electronic technology require them to apply various principles of physics and chemistry. Hence, junior college curricula designed to prepare these workers should include experiences which lead to knowledge and understanding of the essential principles required for the entry-level occupations. In addition, these curricula should provide laboratory experimentation to demonstrate the principle at work in given functional situations.

However, not all principles of physics and chemistry are equally relevant to the occupational needs of these workers. Consequently, it is a fundamental problem in curriculum design to determine which principles to include and which to emphasize. In practice the problem of how much and what kind of chemistry and physics to include is usually solved in one of four ways: (1) by arbitrarily requiring a certain number of semesters of physics and chemistry as prerequisites to the course, (2) by providing concurrent courses in chemistry and physics, (3) by the electronics instructors' emphasizing these principles in their courses, or (4) by some combination of the foregoing. In all cases the identification has had to be made largely through intuition, for currently it is not known with any reliability how to rank any given principle with respect to its importance to technical workers in general.

It is the purpose of this study to determine as accurately as possible the relative importance of various principles of chemistry and physics for instruction in electrical and electronic technology. Note that it is not an investigation of ways to teach the principles, but only of their practical importance for electrical and electronic technicians.

Related Studies

Attempts to isolate the knowledge and skills functionally related to specific occupations have been characteristic of other research projects in vocational education. The Orange County Survey[2] (Orange County, California) of 44 industrial supervisors in the electronics field is an example.

In an extensive survey of San Fernando Valley industries and schools, Donald Dauwalder[3] concludes that the concentration on mathematics and science in technical education should continue, but that the offerings need to be changed to meet the differing requirements of various occupations. However, he did not attempt to indicate the direction these changes should take.

Other studies have been more specific. Twin Cities Technicians,[4] a report published by Michigan State University, listed seven science topics, the understanding of which was considered necessary for technicians to perform on the job. Of these seven, electricity and magnetism, sound, and light were listed as necessary to the electronic technician.

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[2] John L. Buller, Orange Coast College Electronic Computer Survey, Orange Coast College, mimeographed report, Costa Mesa, 1960, pp. 43.

[3] Donald Dauwalder, Education and Training for Technical Occupations, Los Angeles City Junior College District, Los Angeles, 1961, p. 105.

[4] George L. Brandon, Twin Cities Technicians, Michigan State University, East Lansing, 1958, pp. 44-49.

Lawrence Stewart, in a chapter on "Electrical and Electronic Technology," listed the following science topics as essential to the research and development technician in electronics: electricity and magnetism; heat, light, and sound; electron physics; statics and dynamics; kinematics; kinetics, mechanics of materials. Stewart concluded, however, "The data gathered in this study, with few exceptions, strongly support the conclusion that high level mathematics and science skills are not used by electronics and chemical technicians in the performance of their jobs."[5]

In sum, numerous studies have listed the skills and abilities necessary to perform on the job. Detailed lists of the job functions performed by technical workers in the electronics industry have been developed. But these studies did not approach the specific problem in a manner to answer the question, "What Principles?"

Design of the Study

In general, the procedure followed to establish the relative importance of the various principles of chemistry and physics was this: scores of chemical and physical principles were subjected to evaluation, on the basis of their applicability, by a jury representing all who might be able to judge their relevance for technicians. The following pages discuss the principles, the means of their evaluation, and the evaluators.

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[5] Lawrence H. Stewart and Arthur D. Workman, Mathematics and Science Competencies for Technicians, California State Department of Education, Bulletin, Vol. XXIX, No. 12, Sacramento, 1960, p. 45.

Selection of Principles

The initial step in defining the scientific principles needed in electrical-electronic technology was to isolate the principles that might possibly be applicable. To this end, course outlines in physics, chemistry, and electronics were solicited from the junior colleges in California, and the most commonly used texts were requested from the publishers. From these sources a preliminary list of scientific principles was developed.

This list did show in part what was actually being done in the junior colleges, but it was unsatisfactory from the standpoint that evidence was not available to prove that the items on the list were actually principles. Establishing the list as a list of principles was in itself a major task. This preliminary list was therefore abandoned in favor of a list of principles which had been established and which had been subject to extensive review.

This second list of principles, which was used in the study, came from an original investigation by Harold E. Wise.[6] Wise's list was designed to include principles that were of importance to general education. At first glance it would appear that the principles would tend to be too elementary in nature for review in connection with electronics. On the other hand, a list of proven principles would provide a better base than a list of unproven principles. Furthermore, the study by Wise had been brought up to date and revised as late as December, 1962.[7] In the revision items were retained if they met the criteria used to establish them as principles. These criteria are:

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[6] Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education, Ph.D. dissertation, University of Michigan, 1941.

1. The statement must be a comprehensive generalization describing some fundamental process, constant mode of behavior, or property relating to natural phenomena.
2. The item must be true without exception within the limitations stated specifically.
3. It must be capable of illustration.
4. It must not be a definition.

Wise's list of principles was not exhaustive, but it did appear to identify a majority of the fundamental principles. From the 1962 revision of the Wise study, 240 principles were selected for review in connection with the study of electrical-electronic technology.

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[7] The Major Principles of Physics, Chemistry, and Geology of Importance for General Education, U. S. Department of Health, Education, and Welfare, Office of Education, Circ. No. 308-IV, OE 29025, Washington, Jan., 1961.

These 240 items cover fifteen main topics, as shown below:

TOPIC	NUMBER OF ITEMS
General Properties of Energy and Matter	9
Mechanics of Solids	23
Mechanics of Liquids	7
Mechanics of Gases	12
Heat	29
Sound	16
Light	28
Magnetism	5
Static Electricity	6
Current Electricity	27
Atomic Energy and Radiations	18
The Chemical Nature of Matter	14
The Structure of Matter	21
Solutions and Colloids	11
Ions in Solution - Electrolytes	14
	240

The listing of all the items for each topic is shown in the appendix.

The Evaluators

The 240 principles were rated by three groups independently; (1) Technical Workers, (2) Electronics Instructors, and (3) an Expert Jury. Following is a discussion of the selection and characteristics of these people, followed by tables of selected personal data.

Technical Workers

Technical workers were selected on a state-wide basis from employees who had agreed to participate in the study. Participating companies supplied the names and addresses of technical workers in the research and development area whom they considered among the best in their employ. They were asked to select men whose job functions most nearly approximated the research project's definition of research and development. The definition supplied to the companies was as follows:

> Works from schematics and/or verbal instructions to build breadboards of design circuits and prototypes (the initial model of production item). Sets up testing procedures and designs test programs to check out production items. Designs or participates in the design of electro-mechnical packaging and sets up environmental test procedures. Checks and calibrates prototypes of production items; makes modifications and re-designs circuits when and where necessary. Uses complete line of electronic test equipment.

A questionnaire on the 240 physical science principles and a personal data sheet were mailed to each of the technical workers thus identified, with an accompanying letter requesting their cooperation. This approach was used in order to limit the amount of industry time consumed in the research project; it had been tested in a small pilot study to be sure that the responses solicited in this fashion did not differ significantly from the responses solicited on the industries' premises.

The ninety-three technical workers contacted in this fashion returned 51 usable questionnaires (56% of those mailed). This could be construed as being less than a satisfactory response; however, there were some mitigating circumstances that decreased the over-all number of possible responses. In three cases the individual had left the employ of the company that supplied his name; in four other cases the company personnel office supplied the wrong address. Therefore, the returns actually represented 60% of the technical workers contacted.

The modal response to the items of personal data would characterize the typical technical worker for this study as a young man between 21 and 25 who has pursued his formal education beyond two years of college, through two semesters of chemistry and physics, and mathematics through calculus. He has had experience in research and development in electronics in addition to other electronics experience and is upwardly mobile within the industry. This group of technical workers has slightly more formal education and mathematics background than the technical workers included in the previous study.[8]

Instructors

Questionnaires were mailed to sixty-five instructors of electronics in California public junior colleges. A concerted effort was made to solicit a respectable number of responses to the questionnaire. To this end follow-up letters were sent to the presidents of the junior colleges where instructors had not responded, asking for their help in getting the questionnaires returned. This seemed to the the most efficient method since the initial questionnaire was sent to the presidents with a request that they have one of their more capable electronics instructors respond. As a result 55 questionnaires were returned (85%), two accompanied by a note from the junior college presidents to the effect that no one on their staff was qualified to respond. Two others were rejected because all items had the same response. Thus, there were 51 usable responses (78%).

Instructors responsible for the preparation of technical workers for the electrical-electronic industry are influenced in their attitude toward physical science principles by two fundamental factors: (1) their work experience, and (2) their technical background in the physical sciences. Both of these factors differ widely among instructors of electrical-electronic programs in the California junior colleges. Therefore, the instructors would react to the principles of physical science from different points of view. It was therefore important to study the extent of agreement of a carefully selected "expert jury"

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[8] Melvin L. Barlow and William John Schill, op. cit., p. 132.

whose practical and theoretical training made them relative authorities with regard to the physical science principles under study.

Expert Jury

An expert jury of 11 persons was selected to react to the principles of physical science in order to have an additional rating for comparative purposes.

In the case of the jury a strong relationship existed between educational achievement and the number of semesters of physics completed, and also between educational achievement and the number of semesters of mathematics completed. All of the members of the jury had studied calculus as a minimum, and some had pursued the study of mathematics into more advanced courses. The relationship between mathematics, physics, and formal education was expected, since the jury was especially selected to be overtrained, or at least adequate, with respect to the occupational requirements of technical workers. There was only slight relationship between educational achievement of the jury and semesters of chemistry completed.

The work experience background of the jury varied considerably. Two of the jury had work experience in research and development only; four had work experience in electronics some of which was in the area of research and development; five had no research and development experience in their electronics background.

Comparison of Technicians and Instructors

The Kolmogorov-Smirnov two-sample test was used to compare the distribution of the instructors with the distribution of the technical workers on three variables, age, educational attainment, and occupational experience. The result indicated that there was no significant difference between the instructors and the technical workers in terms of educational attainment, but there was a difference significant at the one-percent level for occupational experience and age, with the instructors being older and having less experience in the area of research and development. This was to be expected because of the manner in which technical workers were selected.

Personal Data for Technical Workers, Instructors, and Jury

TABLE I

PERCENTAGE DISTRIBUTION OF TECHNICAL WORKERS ON EIGHT ITEMS OF PERSONAL DATA

Educational Attainment	
High School	8
High School plus	32
A.A. or equiv.	16
A.A. plus or equiv.	44
	100

Occupational Experience	
Research and Development only	8
Electr. exp. with some R & D	40
Electr. exp. but no R & D	48
Some electronic experience	4
	100

Age	
21 to 25	52
26 to 30	20
31 to 35	4
36 to 40	8
41 to 45	16
	100

Semesters of Chemistry	
0	28
1	11
2	31
3	8
4	15
9	7
	100

Semesters of Physics	
0	24
1	4
2	48
4	8
5	8
9	8
	100

Mathematics Attainment	
Algebra	24
Trigonometry	8
Introd.to Calc.	8
Calc.and beyond	60
	100

Mobility	
horiz. mobile	9
stable	39
upward.mobile	52
	100

Job Classification	
Test	52
R & D	40
Computer	8
	100

TABLE II
PERCENTAGE DISTRIBUTION OF ELECTRONICS INSTRUCTORS ON THREE ITEMS OF PERSONAL DATA

Educational Attainment	
High School	0
High School plus	14
A.A. degree or equivalent	65
A.A. degree plus or equivalent	7
B.S. degree or equivalent	4
B.S. degree plus or equivalent	3
M.A. degree or equivalent	4
M.A. degree plus or equivalent	3

Occupational Experience		Age	
Research and Development only	0	21 to 25	6
Electronic exp.w. some R & D	10	26 to 30	12
Electronic exp. but no R & D	22	31 to 35	15
Some electronic experience	10	36 to 40	6
No electronic experience	58	41 to 45	20
		46 to 50	3
		51 to 55	16
		56 to 60	18

TABLE III

PERCENTAGE DISTRIBUTION OF THE JURY ON SIX ITEMS OF PERSONAL DATA

Educational Attainment	
A.A. plus or equivalent	18
B.S. or equivalent	36
B.S. plus or equivalent	18
M.A. or equivalent	9
M.A. plus or equivalent	19
	100

Occupational Experience	
Research and Development only	18
Electronic experience some R&D	36
Electronics experience, no R&D	46
	100

Age	
26 to 30	16
31 to 35	16
36 to 40	8
41 to 45	8
46 to 50	44
51 to 55	8
	100

Semesters of Chemistry	
2	36
3	9
4	9
5	9
6	19
7	9
8	9
	100

Semesters of Physics	
1	9
2	0
3	9
4	9
5	27
6	9
9	37
	100

Mathematics Attainment	
7 Introduction to Calculus	9
8 Calculus and beyond	91
	100

Method of Evaluation

All of the groups rated the 240 principles in the following manner: each individual judged each separate principle as essential to the technical worker, of uncertain value, or of no value. The form of the questionnnaire required that these estimations be made as number values, 3, 2, and 1 respectively. The form of the statements of valuation was generally the same for all persons surveyed, but did vary slightly. On the technician's questionnaire the number values were described as follows:

3 = broad application in day-to-day work
2 = limited application in day-to-day work
1 = little or no application in day-to-day work

For instructors and the expert jury the wording was:

3 = the principle is essential to technical workers of the kind described
2 = the principle's value to these workers is uncertain
1 = the principle is of little or no value to these workers

In order to establish a group's rating of a given principle, the percentage of group members assigning it to each of the three categories (3, 2, 1) was calculated. The category assigned by the largest percentage of members was then called the modal response. For example, if 43 of 51 instructors rated a principle as of uncertain value (2), the principle is reported as having received from the instructors a modal response of 2.

To place the principles in rank order, the mean response for each principle was also calculated. This is the arithmetical mean of the group's responses: that is, the sum of the individual responses divided by the number of responses. For Example, if six jurors rate a given principle at 3, three rate it at 2, and two rate it at 1, the sum of the ratings is 26, and the mean response is 26/11, or 2.36.

As will be seen in the following section, "Results of the Study," ratings were calculated for the groups separately, and these ratings were compared with each other as a means of estimating the reliability of the ratings.

Results of the Study

The actual ranking of the principles is presented in the appendix, where the principles are given in the order assigned them by the combined group of technicians, instructors, and experts. The following paragraphs discuss the salient features of the ratings of items by the various groups, and the similarities and differences among those ratings. The principles are discussed both individually and as constituents of topics, by which term is meant the several headings under which scientific principles are commonly grouped, for example, Light, Sound, Magnetism, and so on.

The Groups' Evaluations

Technicians. The modal responses of the technicians placed 41 items in the broad application category, 6 items in the limited application category, and 191 items in the little or no application category. Two other items had a bimodal distribution. Of the 41 items in the broad application category, 38 were in the four topics comprising the core of electronics (Current Electricity, Static Electricity, Magnetism, and Atomic Energy and Radiation).

To estimate the influence of diverse experience on the technicians' evaluations, several items of their background were analyzed and compared with their ratings of the principles. The responses of the technicians who were high on chemistry, physics, mathematics, or all three were compared statistically with the total group of technicians. This comparison revealed no significant differences, thus it may be said that the technical worker's response was not affected by his attainment in chemistry, physics, or mathematics. A similar negative effect was demonstrated for overall educational attainment. However, when they were grouped by job classification, the technicians' responses did differ sufficiently to be significant at the one-percent level for 32 items. In other words, the kind of work done has some measureable influence upon the technician's rating of items.

Instructors. Individual instructors differed from each other in their responses to any given item, but the modal responses of the group of instructors showed them giving 140 items a rating of essential, 32 items a rating of doubtful, and 67 a rating of no value. One item had an equal number of responses in all three categories. The 140 items in the essential category included all 56 items that comprise the four topics, Current Electricity, Static Electricity, Magnetism, and Atomic Energy and Radiation--the topics comprising the core of electronics.

The instructors' responses were statistically compared with elements of their background--age, education, and occupational experience--in order to appraise the influence of these elements upon the instructors' ratings. No measureable influence could be ascribed to these items.

Expert Jury. The modal responses of the experts categorized 106 items as essential, 50 items as doubtful, and 84 items as of no value. The 106 items called essential included 50 of the 56 principles constituting the four topics basic to electronics.

Comparison of the Groups' Responses

Statistical comparison of the instructors' ratings of individual principles with those of the technicians revealed significant differences at the one-percent level on 134 items. In each case the instructors rated the item higher on the scale (more nearly essential) than did the technicians.

Statistical comparison of the expert jury's ratings with those of the other groups revealed that at the one-percent level there was a significant difference between the experts and the technicians on 40 items. The difference was always in the same direction: the expert jury rated the principles as more nearly essential than did the technicians. A similar comparison of the expert jury with the instructors showed that the two groups differed significantly on 79 items. In this case the instructors were more likely to rate a principle as essential than were the experts. To summarize these comparisons, technicians generally rated items as less important than did either the expert jury or the instructors, and the experts rated items as less important than did the instructors.

Principles Ranked by Topics

The foregoing discussion has indicated the variation among the different groups in their rating of the 240 scientific principles. It was shown, for example, that the technicians considered 41 items essential, while the instructors placed 140 items, and the expert jury 106 items, in that category. It has been shown too that any given item is likely to be considered more important by the expert jury than by the technicians, and still more important by the instructors. These observations would seem to indicate that the results of the questionnaire confuse rather than resolve the issue of scientific principles needed in electrical-electronic technology. This is not the case.

The 240 scientific principes are comprised in 15 topics. When the groups' evaluations are analyzed not by individual principle, but by topic, a more coherent pattern emerges. In the first place, the mean response of each group was used to compute a rank order of topics for each group. The results of this computation are given in Table IV:

TABLE IV

RANK ORDER OF 15 TOPICS BY TECHNICAL WORKERS, JURY, AND INSTRUCTORS

Topic	Technicians	Jury	Instructors
General properties of energy and matter	15	13	13
Mechanics of solids	6	6	6
Mechanics of liquids	12	10	11
Mechanics of gases	10	11	10
Heat	8	9	9
Sound	5	4	5
Light	9	8	7
Magnetism	3	3	2.5
Static electricity	2	2	2.5
Current electricity	1	1	1
Atomic energy and radiations	4	5	4
The chemical nature of matter	11	12	12
The structure of matter	7	7	8
Solutions and colloids	14	15	15
Ions in solutions - electrolytes	13	14	14

In connection with Table IV, note the following points:

(1) Of the 41 principles the technicians deemed essential, 38 are included in the top four topics, which are also the core topics for electronics.

(2) In their 140 essential principles, the instructors included all 56 principles comprised in the top four topics. (3) The expert jury, in its 106 essential principles, included 50 of the 56.

The three groups' rankings of the 15 topics were compared with each other statistically to appraise their relative agreement. First, within each topic the principles were ranked according to the mean response of each group. Second, the rank order of principles within each topic was correlated among the three groups. These correlations are shown in Table V:

TABLE V
RANK ORDER CORRELATIONS BETWEEN TECHNICAL WORKERS, JURY, AND ELECTRONICS INSTRUCTORS ON THE ITEMS WITHIN 15 TOPICS OF THE QUESTIONNAIRE

	TOPICS	INSTR. & TECH. WORKERS	INSTR. & JURY	JURY & TECH. WORKERS
1	General properties of energy and matter	.385	.992*	.559
2	Mechanics of solids	.583*	.994*	.549*
3	Mechanics of liquids	.372	.723	.455
4	Mechanics of gases	.611	.822*	.768*
5	Heat	.469*	.909*	.435
6	Sound	.669*	.875*	.650*
7	Light	.616*	.935*	.639*
8	Magnetism	.825	.925*	.900*
9	Static electricity	.115	.915*	.219*
10	Current electricity	.344	.151	.562*
11	Atomic energy and radiations	.692*	.860*	.589
12	The chemical nature of matter	.511	.889*	.544*
13	The structure of matter	.552	.915*	.610*
14	Solutions and colloids	.850*	.798*	.873*
15	Ions in solutions - electrolytes	.108	.875	.132
Z		1.96**	3.09*	2.10**

* Significant at one-percent level

** Significant at five-percent level

Of the resulting 45 correlations, 30 were significant at the one-percent level of confidence, which seems to indicate that there is general agreement on the relative importance of the items within the topics. To demonstrate this, the correlations were converted to "z" scores to permit their separation, and the resulting means of the "z" scores were interpreted for their significance. This demonstrated that the overall relationship between technical workers and instructors on the rank order of the items within the topics was 1.96, between the instructors and the expert jury 3.08, and between the jury and technical workers 2.10. All three of the resulting "z" scores are significant at the five-percent level.

In view of the foregoing, it may be said that the three groups agree on the relative importance of the 15 topics. The agreed rank order, from the most essential to the least essential topic, is as follows:

1. Current electricity
2. Static electricity
3. Magnetism
4. Atomic energy and radiations
5. Sound
6. Mechanics of solids
7. The structure of matter
8. Light
9. Heat
10. Mechanics of gases

11. Mechanics of liquids
12. The chemical nature of matter
13. General properties of energy and matter
14. Ions in solutions - electrolytes
15. Solutions and colloids

This rank order of topics does not imply that topics lower on the list contain no essential items. It means only that taking the topics in total, they are in that rank importance.

Presentation of the Evaluation

One of the difficulties in defining curriculum content is that time limitations prohibit the inclusion of many pieces of information that are known to be desirable. This report cannot alleviate that problem nor shall it attempt to. Rather, the 240 items investigated in the research project are presented in two fashions on the following pages: first, with the topics in the rank order mentioned above and with the items in their rank order under each topic; second, with items in rank order without respect to the topics under which they fall.

It is hoped that this will permit those responsible for the definition of the curricula in electrical-electronic technology in the California public junior colleges to select more accurately the physical science principles which time will permit to be included in the curriculum.

Note on the Value of the Principles for Practical Work Versus that for General Education

Rank orders for the topics and items within the topics were computed from the order assigned to the 240 principles on the basis of their application to general education. These rank orders were then correlated with the rank order assigned by the respondents in this research project. The resulting correlations between the general education order for the topics and the order assigned by the instructors, jury, and the technical workers were .75, .500, and .429 respectively. All three correlations were less than significant and can be taken as an indication that the order of the topics as proposed for general education is not acceptable for programs in which there needs to be a functional relationship between curriculum content and a specific field of work.

The items within each topic were rank ordered on the basis of the ranks assigned for general education, and this general education order was then correlated with the rank order of items within the topics assigned by the total group of this study. The resulting correlations varied from .713 to .114, none of which were sufficiently high to be significant. This reinforces the previous statement that the general education requirements in the physical sciences as proposed by Wise[9] do not fulfill the more specific requirements in the area of electrical-electronic technology.

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[9] Harold E. Wise, op. cit.

THE ROLE OF THE PHYSICAL SCIENCES IN ELECTRICAL-ELECTRONIC TECHNOLOGY

APPENDICES

I. Rank Order of Topics and Items Within Topics

II. Rank Order of Items Within the Whole List

RANK ORDER OF TOPICS AND ITEMS WITHIN THE TOPICS

A. CURRENT ELECTRICITY

2 Electrical power is directly proportional to the product of the potential difference and the current.

2 In a parallel circuit the total current is the sum of the separate currents, the voltage loss is the same for each branch, and the total resistance is less than the resistance of any one branch.

2 In a series circuit the current is the same in all parts the resistance of the whole is the sum of the resistance of the parts, and the voltage loss of the whole is the sum of the voltage losses.

4 In a transformer the ratio between voltages in the primary and secondary circuits is the same as that between the number of turns of wire in these circuits.

5 The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.

6 All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.

7.5 An electrical charge in motion produces a magnetic field about the conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it.

7.5 An induced current always has such a direction that its magnetic field tends to oppose the motion by which the current was produced.

8 Alternating current charges a condenser twice during each cycle inducing opposite charges on the two plates with the result that a current appears to flow through the condenser.

9 An e.m.f. is induced in a circuit whenever there is a change in the number of lines of magnetic force passing through the circuit.

A. CURRENT ELECTRICITY (cont'd)

10 Whenever a high-frequency oscillating current produces in the field around it oscillating electric and magnetic fields, energy in the form of an electromagnetic wave is transmitted through space.

11.5 The amount of heat produced by an electric current is proportional to the resistance, the square of the current, and the time of flow.

11.5 Electro-magnetic waves may produce electrical oscillation in a capacitive circuit which is so adjusted as to oscillate naturally with the same frequency as that of the incoming waves.

13 An electric current will be produced in a closed circuit including two strips of different metals if one of the junctions is heated or cooled.

14 An electric current may be produced in four ways: by rubbing or friction, by chemical action, by the use of magnets, and by induction.

15 By means of high frequency generators or vacuum-tube oscillators, sustained or continuous oscillations can be produced in a condenser circuit. Their intensity is made to vary with audio-frequency currents in a transmitter circuit to produce radio waves.

16 Gases conduct electric currents only when ionized.

17 The resistance of a metallic conductor depends on the kind of material from which the conductor is made, varies directly with the length, inversely with the cross-sectional area, and increases as the temperature increases.

18 An electric current will flow in the external circuit, when two metals of unlike chemical activity are acted upon by conducting solution, the more active metal being charged negatively.

19 When a current-carrying wire is placed in a magnetic field, there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field.

20 The magnitude of an induced e.m.f. is proportional to the rate at which the number of lines of magnetic force change and to the number of turns of wire in the coil.

21 The capacitance of a capacitor varies directly with the area of the plate and inversely as the thickness of the insulation between them.

A. CURRENT ELECTRICITY (cont'd)

22 Electrons will always flow from one point to another along a conductor if this transfer releases energy.

23 Energy in kilowatt hours is equal to the product of amperes, volts, and time (in hours), divided by one thousand.

24 Positively charged ions of metals may be deposited on the cathode, as atoms, when a direct current is sent through an electrolyte.

25 Two electro-magnetic waves having the same frequency and amplitude and traveling in normally the same direction will interfere constructively or destructively, depending upon whether they are in phase or out of phase.

26 The mass of any substance set free by electrolysis is proportional to the current flowing and the time of flow, if the quantity of electricity is kept constant the masses of the various substances set free are proportional to their electrochemical equivalents.

B. STATIC ELECTRICITY

1 Like electrical charges repel and unlike electrical charges attract.

2 In an uncharged body there are as many protons as electrons and the charges neutralize each other; while a deficiency of electronics produces a negative charge.

3 Charges on a conductor tend to stay on the surface and to be greatest on the sharp edges and points.

4 Electrons have both a magnetic and an electric field.

5 Electrostatic induction is the separation of charges on a conductor through the influence of a neighboring charge.

6 The force of attraction or repulsion between two small charged bodies varies directly as the product of the two charges and inversely as the square of the distance between the charges.

C. MAGNETISM

1 Pieces of iron, steel, cobalt, or nickel may become magnetized by induction when placed within a magnetic field.

2 Like magnetic poles always repel each other and unlike magnetic poles always attract each other.

3 A magnet always has two poles and is surrounded by a field of force.

4 The force of attraction or repulsion between two magnetic poles varies directly as the product of the pole strengths and inversely as the square of the distance between the poles.

5 Magnets depend for their properties upon the arrangement of the metallic ions of which they are made up.

D. ATOMIC ENERGY AND RADIATIONS

1 Electrons are emitted from any sufficiently hot body.

2 A number of substances will emit electrons and become positively charged when illuminated by light.

3 All matter is made up of protons, neutrons, and electrons.

4 In a tube which contains gas at low pressure subject to an intense electric field, cathode rays, streams of electrons, move away from the negatively charged terminal at high speeds.

5 Protons and neutrons only are found in the nucleus of an atom.

6 Electrons charge energy levels emitting or absorbing energy.

7 Atoms or molecules may lose electrons when struck by high speed electrons or ions.

8 When a stream of high speed electrons strikes a body, the atoms of the body emit X-rays.

9 Matter may be transformed into energy and energy into matter, the sum total, matter plus energy, remains constant.

10 The mass of an atom is concentrated almost entirely in the nucleus.

D. ATOMIC ENERGY AND RADIATIONS (cont'd)

11 The atoms of radioactive elements are constantly disintegrating by giving off various rays (alpha, beta, and gamma) and forming helium and other elements.

12 Radioactive emission involves nuclear changes.

13 Radioactivity is independent of all physical conditions: heat, cold, pressure, and chemical state.

14 Atoms have great subatomic energy.

15 Elements may be changed into other elements.

16 Atoms may be broken down by bombarding the nucleus with high speed particles such as protons, alpha particles, and neutrons.

17 The distance of successive electron shells from the nucleus of an atom and from each other, are much greater than the dimensions of the nucleus itself.

18 Some elements have more than one atomic weight due to differences in the neutron content of their nuclei.

E. SOUND

1 Sound is produced by vibrating matter and is transmitted by matter.

2 The velocity of a wave is equal to the product of its frequency and wave length.

3 The higher the pitch of a note, the more rapid the vibrations of the producing body.

4 The loudness of a sound depends upon the energy of the sound waves and, if propagated in all directions, decreases inversely as the square of the distance from the source.

5 When energy is transmitted in waves, the medium which transmits the wave motion does not move along with the wave, but the energy does.

6 Sound waves or other energy impulses may set up vibrations in a body the amplitude of which is increased if the impulses are exactly timed to correspond to any one of the natural periods of vibration of the body.

E. SOUND (cont'd)

7 Two sound waves of the same or nearly the same frequency will destructively interfere with each other when the condensations of the one coincide with the rare factions of the other provided that the directions of propagation are the same.

8 Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear.

9 Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection.

10 When a sounding body is moving toward or away from an observer the apparent pitch will be higher or lower respectively, than the true pitch of the sound emitted.

11 The speed of sound increases with an increase in temperature of the medium conducting it.

12 Each vibrating particle in a wave front of any wave motion may be considered as a secondary source of spherical wavelets which spread out from their sources with the velocity of the primary wave.

13 The quality of a musical tone is determined by the pitch and intensity of the different simple tones or harmonies into which it may be resolved.

14 Harmonious musical intervals correspond to very simple frequency ratios.

15 The velocity of sound is directly proportional to the square root of the elasticity modulus and inversely proportional to the square root of the density of the transmitting medium.

16 The frequency of the vibration of a stretched string is inversely proportional to its length, diameter, and square root of its density; and directly proportional to the square root of the stretching force.

F. MECHANICS OF SOLIDS

1 The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.

2 When two forces act upon the same object, the resultant is the diagonal of a parallelogram whose sides represent the direction and magnitude of the two forces. A single force represented by the diagonal may be resolved into two forces represented by the side of the parallelogram.

3 When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice versa.

4.5 When forces act in the same direction, the resultant is their algebraic sum.

5 When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.

6 The amount of heat developed in doing work against friction is proportional to the amount of work thus expended.

7 A spinning body offers resistance to any force which changes the direction of the axis about which the body rotates.

8 The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition.

9 Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.

10 When a body exerts a force on a second body, the second body exerts an equal and opposite force on the first.

11 The energy which a body possesses on account of its motion is called kinetic energy and is proportional to its mass and the square of its velocity.

12 In the lever, the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.

13 Sliding friction is dependent upon the nature and coordination

F. MECHANICS OF SOLIDS (cont'd)

of the rubbing surfaces, proportional to the force pressing the surfaces together, and independent of area of contact.

14 The amount of momentum possessed by an object is proportional to its mass and to its velocity.

15 The speed gained by a body with constant acceleration is equal to the product of the acceleration and the time.

16 The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of that force.

17 The distance a body travels, starting from rest with a constant acceleration, is one-half the acceleration times the square of the time.

18 Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation.

19 In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.

20 Centrifugal force is directly proportional to the square of the velocity, to the mass, and inversely proportional to the radius of rotation.

21 At any point on the earth's surface all bodies fall with a constant acceleration which is independent of the mass or size of the body if air resistance be neglected.

22 The period of a pendulum swinging through short arcs is independent of the weight of the body but varies directly as the square root of the length and inversely as the square root of the acceleration of gravity.

23 Movements of all bodies in the solar system are due to gravitational attraction and inertia.

G. THE STRUCTURE OF MATTER

1 Most atoms have the property of losing, gaining, or sharing a number of outer shell electrons.

G. THE STRUCTURE OF MATTER (cont'd)

2 The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.

3 The orderly arrangement of molecules, atoms, or ions in crystals give crystals regular form.

4 Elements are made up of small particles of matter called atoms which are alike in the same element (except of occasional differences in atomic weight, i. e. isotopes) but different in different elements.

5 Atoms of all elements are made up of protons, neutrons and electrons; and differences between atoms of different elements are due to the number of protons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.

6 A few elements are inert or chemically inactive because their atoms are so constructed as to be complete in themselves; i. e. their outer electron rings have no tendency to gain or lose electrons.

7 The valence of an atom is determined by the number of electrons it gains, loses, or shares in chemical reactions.

8 All substances are made up of small particles called molecules, which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances.

9 Non-metals comprise a group of elements whose atoms tend to gain or share electrons and whose compounds, when dissolved in polar solvents, are capable of forming negative ions.

10 All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these constituents.

11 Metals may be arranged in an activity series according to their tendency to pass into ionic form by losing electrons.

12.5 Metals comprise a group of elements (other than hydrogen) whose atoms have a tendency to lose electrons readily and whose compounds when dissolved in polar solvents are capable of forming positive ions.

G. THE STRUCTURE OF MATTER (cont'd)

12.5 Non-metals may be arranged in an activity series according to their tendency to pass into ionic form by gaining electrons.

14 The properties of the elements show periodic variations with their atomic numbers.

15 The energy shown by atoms in completing their outer shell by adding, losing, or sharing electrons determines their chemical activity.

16 Oxidation always involves the removal or sharing of electrons from the element oxidized, while the reduction always adds or shares with the element reduced.

17 The specific heats of many elements are approximately inversely proportional to their atomic weights.

18 Equal amounts of heat raise equal numbers of atoms of all elements in the solid state through nearly equal intervals of temperature.

19.5 Equal volumes of all gases under similar conditions of temperature and pressure contain very nearly the same number of molecules.

19.5 Oxidation and reduction occur simultaneously and are quantitatively equal.

21 The gravimetric composition of a compound may be found by multiplying the atomic weights of the elements by their subscripts in the formula of the compound.

H. LIGHT

1 Energy is often transmitted in the form of waves.

2 When waves strike an object, they may either be absorbed, transmitted, or reflected.

3 Waves travel in straight lines while passing through a homogeneous or uniform medium.

4.5 Light travels in straight lines in a medium of uniform optical density.

H. LIGHT (cont'd)

4.5 When light rays are absorbed, some of the light energy is transformed into heat energy.

6 The intensity of illumination decreases as the square of the distance from a point source.

7 The darker the color of a surface, the better it absorbs light.

8 When light is reflected, the angle of incidence is equal to the angle of reflection.

9 Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object.

10 The speed of light in any given substance bears a constant ratio to the speed of light in air.

11 If a beam of light falls upon an irregular surface, the rays of light are scattered in all directions.

12 All rays passing through the center of curvature of a mirror are reflected upon themselves.

13 The colors of objects depend upon what light rays they transmit, absorb, or reflect.

14 Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors.

16 When light is incident upon a medium in which it will travel faster and when the angle of incidence is greater than the critical angle, it is totally reflected.

16 The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.

16 Incandescent solids and liquids emit all wave lengths of light and give a continuous spectrum.

18 In a plane mirror a line running from any point on the subject to the image of that point is perpendicular to the mirror.

19 When white light passes through a substance that absorbs some waves and not others, certain bands of color are missing with the production of an absorption spectrum.

H. LIGHT (cont'd)

20 Luminous vapors and gases emit only certain kinds of light producing bright-line spectra.

21 When parallel light strikes a concave spherical mirror, the rays, after reflection, pass directly through the principal focus only if the area of the mirror is small compared to its radius of curvature.

22.5 When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal.

22.5 An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed.

24 When a body which emits a bright line spectrum is moving toward or away from the observer, the lines are shifted toward the short or long wave length end of the spectrum respectively.

25 The curvature of a wave front will be changed a given amount by a lens; namely 1/F.

26 A beam of light may become plane polarized as the result of any circumstance which results in the suppression of one of the rectilinear components of the vibration without affecting the components at right angles to it.

27 The sum of the reciprocals of the conjugate focal lengths of a lens or mirror equals the reciprocal of the principal focal length.

28 The dimensions of an image produced by a lens or a mirror are to the dimensions of the object as their respective distances from the lens or mirror are to each other.

I. HEAT

1 Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature.

2 When two bodies of different temperature are in contact, there is a continuous transference of heat energy, the rate of which is directly proportional to the difference of temperature.

I. HEAT (cont'd)

3 Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces.

4 Radiant energy travels in waves along straight lines, its intensity at any distance from a point source is inversely proportional to the square of the distance from the source.

5 The total change in length of a metal bar is equal to its coefficient of linear expansion times the original length times the change of temperature in degrees Centigrade.

6 The lower the temperature of a body, the less the amount of energy it radiates; the higher the temperature, the greater is the amount of energy radiated.

7 Heat is conducted by the transfer of kinetic energy from molecule to molecule.

8 The average speed of molecules increases with the temperature and pressure.

9 Every pure liquid has its own specific boiling and freezing point.

10 Heat is transferred by convection, in currents of gases or liquids the rate of transfer decreasing with an increase in the viscosity of the circulating fluid.

11 The amount of heat which a constant mass of liquid or solid acquires when its temperature rises a given amount is identical with the amount it gives off when its temperature falls by that amount.

12 When a gas expands, heat energy is converted into mechanical energy.

13 The more nearly vertical the rays of radiant energy, the greater the number that will fall upon a given horizontal area, and the greater is the amount of energy that will be received by that area.

14 Heat is liberated when a gas is compressed, and is absorbed when a gas expands.

15 The presence of a dissolved substance will cause the resulting solution to boil at a higher temperature and to freeze at a

I. HEAT (cont'd)

lower temperature than pure water.

16.5 Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.

16.5 The higher the temperature of the air, the greater the amount of moisture required to saturate it.

18 The boiling point of any solution becomes lower as the pressure is decreased and higher as the pressure is increased.

19 Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn.

20 Each combustible substance has a kindling temperature which varies with its condition, but may be greater or less than the kindling temperature of some other substance.

21 A change in state of a substance from gas to liquid, liquid to solid, or vice versa, is usually accompanied by a change in volume.

22 Bodies of land heat up and cool off more rapidly and more readily than bodies of water.

23 The rate of evaporation of a liquid varies with temperature, area of exposed surface, and saturation and circulation of the gas in contact with the liquid.

24 Freezing point depression and boiling point elevation are proportional to the concentration of the solution.

25 The pressure of a saturated vapor is constant at a given temperature, and increases with an increase of temperature.

25 The rate of vaporization decreases with an increase of concentration of the vapor in the gas in contact with the liquid, the temperature remaining constant.

26 The atmosphere of the earth tends to prevent the heat of the earth's surface from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day.

I. HEAT (cont'd)

27 Substances which expand upon solidifying have their melting points lowered by pressure; those which contract upon solidifying have their melting points raised by pressure.

28 The principal cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressure to places of low atmospheric pressure.

J. MECHANICS OF GASES

1 The atmospheric pressure decreases as the altitude increases.

2 A fluid has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement.

3 The volume of an ideal gas varies inverseley with the pressure upon it, providing the temperature remains constant.

4 If the same pressure is maintained, the volume of a gas is varied directly as the absolute temperature.

5 A gas always tends to expand throughout the wole space available.

6 If the volume of a confined body of gas is kept constant, the pressure is proportional to the absolute temperature.

7 The atmospheric pressure decreases with increasing water vapor content, other things being equal.

8 When a mixture of gases is confined, each exerts its own pressure without reference to the pressure exerted by others.

9 Diffusible substances tend to scatter from the point of greatest concentration until all points are at equal concentration.

10 In moving air, wind pressure increases as the square of the velocity.

11 The speed of diffusion of gases varies inversely with the square root of their densities.

J. MECHANICS OF GASES (cont'd)

12 In the northern hemisphere great volumes of air revolve in a counter-clockwise direction, and in the southern hemisphere, they revolve in a clockwise direction.

K. MECHANICS OF LIQUIDS

1 The pressure at a point in any fluid is the same in all directions.

2 As the velocity of flow through a constricted area increases, the pressure diminishes.

3 When pressure is applied to any area of a liquid in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the liquid.

4 A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

5 Any homogeneous body of liquid free to take its own position, will seek a position in which all exposed surfaces lie on the same horizontal plane.

6 The pressure in a fluid in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as the depth and average density of the fluid.

7 The rate of osmosis is directly proportional to the difference in concentration on opposite sides of the membrane.

L. THE CHEMICAL NATURE OF MATTER

1 No chemical change occurs without an accompanying energy change.

2 Every pure sample of any substance, whether simple or compound, under the same conditions will show the same physical properties and the same chemical behavior.

3 Each element has its own characteristic X-ray spectrum.

4 Every chemical element when heated to incandescence in a gaseous state has a characteristic glow and a characteristic spectrum which can be used to identify very small quantities of the element

L. THE CHEMICAL NATURE OF MATTER (cont'd)

and which is related to the molecular and atomic structure of the gas.

5 A pure chemical substance may be prepared from raw materials through utilization of their physical and chemical properties.

6 The heat of formation of any chemical compound equals its heat of decomposition.

7 The total mass of quantity of matter is not altered by any chemical changes occurring among the materials composing it.

8 When different amounts of one element are found in combination with a fixed weight of another element (in a series of compounds) the different weights of the first element are related to each other by ratios which may be expressed by small whole numbers.

9 In every sample of any compound substance formed, the proportion by weight of the constituent elements is always the same as long as the isotopic composition of each element is constant.

10 The materials forming one or more substances, without ceasing to exist, may be changed into one or more new and measurably different substances.

11 The products of reacting substances may react with each other to form the original substance.

12 Reactions occurring at ordinary temperatures are predominantly exothermic.

13 At a definite pressure and temperature, the relative combining volumes of gases and of gaseous products may be expressed approximately in small whole numbers.

14 When a chemical change takes place without the addition of heat from an external source, that substance which has the greatest heat of formation will tend to form.

M. GENERAL PROPERTIES OF ENERGY AND MATTER

1 Energy can be changed from one form to another, or to matter, with exact equivalence.

M. GENERAL PROPERTIES OF ENERGY AND MATTER (cont'd)

2 The distortion of an elastic body is proportional to the force applied provided the elastic limit is not exceeded.

3 Gases may be converted into liquids by reducing the speed of their molecules.

4 All liquids are compressible but only to a slight degree.

5 Fluids have no elastic limit for compression.

6 If the vapor pressure of the water of hydration is greater than that of the moisture of the air, crystals will gradually yield up water to the air, and vice versa.

7 The height to which a liquid rises in a capillary tube is directly proportional to the surface tension of the liquid and inversely proportional to the density of the liquid, and to the radius of the tube.

8.5 The free surface of a liquid contracts to the smallest possible area due to surface tension.

8.5 A liquid will rise in a capillary tube if the contact angle between the liquid and the side of the tube is less than 90° and will be depressed if the contact angle is greater than 90°.

N. IONS IN SOLUTION - ELECTROLYTES

2 Acids and bases are substances which in water solution ionize to give hydrogen and hydroxyl ions, respectively, from their constituent elements.

2 The exchange of the negative and positive ions of acids and bases results in the formation of water and a salt.

2 Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions.

4 The speed of chemical reaction is increased by increasing the concentration of any of the reactants; and is decreased by decreasing the concentration of any of the reactants.

5.5 The activity of an acid or base is proportional to the degree of ionization of the compound when in solution.

N. IONS IN SOLUTION - ELECTROLYTES (cont'd)

5.5 The properties of alloys are dependent upon the relative amounts of their components, the extent of their compound formation, and upon the crystalline structure of the mixture.

7 If stress is applied to a reversible chemical system, there will be a readjustment in the system to relieve the stress.

8 Salts of strong acids and strong bases undergo neglibible hydrolysis, while salts of inactive acids and inactive bases undergo more marked hydrolysis.

9 The rates of many reactions are affected by the presence of substances which do not enter into the completed chemical reaction.

10 All chemical reactions which start with the same quantities of original substances, liberate the same amounts of energy in reaching a given final state, irrespective of the process by which the final state is reached.

11 Simple ionic reactions are typically rapid reactions.

12 Chemical reactions may be carried more nearly to completion by any condition that establishes an unusually low concentration of one of the products.

13 Whenever the product of the concentrations of any two ions in a mixture is less than the value of the ion-product in a saturated solution of the compound formed by their union, this compound, if present in the solid form, will be dissolved.

14 Whenever the product of the concentrations of any two ions in a mixture exceeds the value of the ion-product in a saturated solution of the compound formed by their union, this compound will be precipitated.

O. SOLUTIONS AND COLLOIDS

1 The ingredients of a solution are homogeneously distributed through each other.

2 The solubility of solutes is affected by heat, pressure, and the nature of the solute and solvent.

3 Collodial particles may carry electrical charges.

O. SOLUTIONS AND COLLOIDS (cont'd)

4 Any substance soluble in two immiscible liquids will distribute itself between the two in proportion to its solubility in the two liquids.

5 The solubility of a gas in an inert solvent varies directly with the pressure to which a gas is subjected.

6 Temperature changes, pressure changes, the presence of electrolytes or the presence of oppositely charged particles may cause colloids to precipitate.

7 Surface reactions predominate in all non-homogeneous reactions.

8 Colloids show greater chemical activity than the solid substances in mass, since rates of reaction are proportional to the surface area of the solid, other factors being equal.

9 In a saturated solution, the product of the molar concentrations of the ions is constant.

10 Colloids have the property of absorption to an unusual degree.

11 Suspended particles of colloids have a continuous, erratic movement due to colloidal, molecular, or ion impacts.

RANK ORDER OF ITEMS FOR QUESTIONNAIRE AS A WHOLE

2 In a parallel circuit the total current is the sum of the separate currents, the voltage loss is the same for each branch, and the total resistance is less than the resistance of any one branch.

2 In a series circuit the current is the same in all parts, the resistance of the whole is the sum of the resistance of the parts, and the voltage loss of the whole is the sum of the voltage losses.

2 Electrical power is directly proportional to the product of the potential difference and the current.

4 The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.

5 All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.

6 Alternating current charges a condenser twice during each cycle inducing opposite charges on the two plates with the result that a current appears to flow through the condenser.

7 In a transformer the ratio between voltages in the primary and secondary circuits is the same as that between the number of turns of wire in these circuits.

8 The amount of heat produced by an electric current is proportional to the resistance, the square of the current and the time of flow.

10.5 An induced current always has such a direction that its magnetic field tends to oppose the motion by which the current was produced.

10.5 An electric current may be produced in four ways: by rubbing or friction, by chemical action, by the use of magnets, and by induction.

10.5 An electrical charge in motion produces a magnetic field about the conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it.

10.5 Like electrical charges repel and unlike electrical charges attract.

13 An e.m.f. is induced in a circuit whenever there is a change in the number of lines of magnetic force passing through the circuit.

Rank Order of Items for Questionnaire as a Whole (cont'd)

15.5 An electric current will be produced in a closed circuit including two strips of different metals if one of the junctions is heated or cooled.

15.5 The resistance of a metallic conductor depends on the kind of material from which the conductor is made, varies directly with the length, inversely with the cross-sectional area, and increases as the temperature increases.

15.5 Electro-magnetic waves may produce electrical oscillation in a capacitive circuit which is so adjusted as to oscillate naturally with the same frequency as that of the incoming waves.

15.5 Electrons will always flow from one point to another along a conductor if this transfer releases energy.

18.5 A magnet always has two poles and is surrounded by a field of force.

18.5 Pieces of iron, steel, cobalt, or nickel may become magnetized by induction when placed within a magnetic field.

20.5 Like magnetic poles always repel each other and unlike magnetic poles always attract each other.

20.5 The magnitude of an induced e.m.f. is proportional to the rate at which the number of lines of magnetic force change and to the number of turns of wire in the coil.

23.5 Gases conduct electric currents only when ionized.

23.5 The capacitance of a capacitor varies directly with the area of the plate and inversely as the thickness of the insulation between them.

23.5 Electrons are emitted from any sufficiently hot body.

23.5 In an uncharged body there are as many protons as electrons and the charges neutralize each other; while a deficiency of electrons produces a plus charge on a body and an excess of electronics produces a negative charge.

27 By means of high frequency generators of vacuum-tube oscillators, sustained or continuous oscillations can be produced in a condenser circuit. Their intensity is made to vary with audio-frequency currents in a transmitter circuit to produce radio waves.

Rank order of Items for Questionnaire as a whole (cont'd)

27 Each vibrating particle in a wave front of any wave motion may be considered as a secondary source of spherical wavelets which spread out from their sources with the velocity of the primary wave.

27 An electric current will flow in the external circuit, when two metals of unlike chemical activity are acted upon by a conducting solution, the more active metal being charged negatively.

29 Whenever a high-frequency oscillating current produces in the field around it oscillating electric and magnetic fields, energy in the form of an electro-magnetic wave is transmitted through space.

30 The force of attraction or repulsion between two magnetic poles varies directly as the product of the pole strengths and inversely as the square of the distance between the poles.

31 When a current-carrying wire is placed in a magnetic field, there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field.

33 Energy in kilowatt hours is equal to the product of amperes, volts and time (in hours), divided by one thousand.

33 Sound is produced by vibrating matter and is transmitted by matter.

33 Electrons have both a magnetic and an electric field.

35.5 Charges on a conductor tend to stay on the surface and to be greatest on the sharp edges and points.

35.5 A number of substances will emit electrons and become positively charged when illuminated by light.

37 Two electro-magnetic waves having the same frequency and amplitude and traveling in normally the same direction will interfere constructively or destructively, depending upon whether they are in phase or out of phase.

38 Energy is often transmitted in the form of waves.

39.5 All matter is made up of protons, neutrons, and electrons.

39.5 The force of attraction or repulsion between two small charged bodies varies directly as the product of the two charges and inversely as

Rank order of Items for Questionnaire as a whole (cont'd)

the square of the distance between the charges.

41 Electrostatic induction is the separation of charges on a conductor through the influence of a neighboring charge.

42.5 The higher the pitch of a note, the more rapid the vibrations of the producing body.

42.5 The velocity of a wave is equal to the product of its frequency and wave length.

45 In a tube which contains gas at low pressure subject to an intense electric field, cathode rays, streams of electrons, move away from the negatively charged terminal at high speeds.

45 The loudness of a sound depends upon the energy of the sound waves and, if propagated in all directions, decreases inversely as the square of the distance from the source.

45 Most atoms have the property of losing, gaining, or sharing a number of outer shell electrons.

47 When two forces act upon the same object, the resultant is the diagonal of a parallelogram whose sides represent the direction and magnitude of the two forces. A single force represented by the diagonal may be resolved into two forces represented by the sides of the parallelogram.

48 When waves strike an object, they may either be absorbed, transmitted, or reflected.

49 When forces act in the same direction, the resultant is their algebraic sum.

50 Waves travel in straight lines while passing through a homogeneous or uniform medium.

52 The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.

52 Positively charged ions of metals may be deposited on the cathode, as atoms, when a direct current is sent through an electrolyte.

52 Magnets depend for their properties upon the arrangement of the metallic ions of which they are made up.

Rank order of Items for Questionnaire as a whole (cont'd)

54 Energy can be changed from one form to another, or to matter, with exact equivalence.

55.5 Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature.

55.5 Protons and neutrons only are found in the nucleus of an atom.

57 The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.

58 Atoms or molecules may lose electrons when struck by high speed electrons or ions.

59.5 When energy is transmitted in waves, the medium which transmits the wave motion does not move along with the wave, but the energy does.

59.5 The orderly arrangement of molecules, atoms, or ions in crystals give crystals regular form.

61 When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.

62.5 Electrons charge energy levels emitting or absorbing energy.

62.5 Sound waves or other energy impulses may set up vibrations in a body the amplitude of which is increased if the impulses are exactly times to correspond to any one of the natural periods of vibration of the body.

64.5 Radiant energy travels in waves along straight lines, its intensity at any distance from a point source is inversely proportional the square of the distance from the source.

64.5 Two sound waves of the same or nearly the same frequency will destructively interfere with each other when the condensations of the one coincide with the rarefactions of the other provided that the directions of propagation are the same.

66 Atoms of all elements are made up of protons, neutrons, and electrons; and differences between atoms of different elements are due to the number of protons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.

Rank Order of Items for Questionnaire as a Whole (cont'd)

67.5 Light travels in straight lines in a medium of uniform optical density.

67.5 Elements are made up of small particles of matter called atoms which are alike in the same element (except for occasional differences in atomic weight, i.e., isotopes) but different in different elements.

70 When a sounding body is moving toward or away from an observer the apparent pitch will be higher or lower respectively, than the true pitch of the sound emitted.

70 When a stream of high speed electrons strikes a body, the atoms of that body emit X-rays.

70 A few elements are inert or chemically inactive because their atoms are so constructed as to be complete in themselves; i.e., their outer electron rings have no tendency to gain or lose electrons.

72 The mass of an atom is concentrated almost entirely in the nucleus.

74.5 Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection.

74.5 All substances are made up of small particles called molecules, which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances.

74.5 Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces.

74.5 When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice versa.

77 When light rays are absorbed, some of the light energy is transformed into heat energy.

78 The valence of an atom is determined by the number of electrons it gains, loses, or shares in chemical reactions.

79.5 Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear.

79.5 The intensity of illumination decreases as the square of the distance from a point source.

Rank Order of Items for Questionnaire as a Whole (cont'd)

82 When light is reflected, the angle of incidence is equal to the of reflection.

82 The darker the color of a surface, the better it absorbs light.

82 The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition.

84 Matter may be transformed into energy and energy into matter, the sum total, matter plus energy, remains constant.

85.5 The atoms of all radioactive elements are constantly disintegrating by giving off various rays (alpha, beta, and gamma) and forming helium and other elements.

85.5 The lower the temperature of a body, the less the amount of energy it radiates; the higher the temperature, the greater is the amount of energy radiated.

87.5 The atmospheric pressure decreases as the altitude increases.

87.5 The speed of light in any given substance bears a constant ratio to the speed of light in air.

89 Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object.

92 Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions.

92 Radioactive emission involves nuclear changes.

92 The amount of heat developed in doing work against friction is proportional to the amount of work thus expended.

92 The speed gained by a body with constant acceleration is equal to the product of the acceleration and the time.

92 The mass of any substance set free by electrolysis is proportional to the current flowing and the time of flow, if the quantity of electricity is kept constant the masses of the various substances set free are proportional to their electro-chemical equivalents.

95 The average speed of molecules increases with the temperature and pressure.

Rank Order of Items for Questionnaire as a Whole (cont'd)

96 A spinning body offers resistance to any force which changes the direction of the axis about which the body rotates.

97 The quality of a musical tone is determined by the pitch and intensity of the different simple tones or harmonies into which it may be resolved.

98 Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.

99 If a beam of light falls upon an irregular surface, the rays of light are scattered in all directions.

100 The energy shown by atoms in completing their outer shell by adding, losing, or sharing electrons determines their chemical activity.

102 The speed of sound increases with an increase in temperature of the medium conducting it.

102 No chemical change occurs without an accompanying energy change.

102 Atoms may be broken down by bombarding the nucleus with high speed particles such as protons, alpha particles, and neutrons.

104.5 Radioactivity is independent of all physical conditions; heat, cold, pressure, and chemical state.

104.5 Every pure sample of any substance, whether simple or compound, under the same conditions will show the same physical properties and the same chemical behavior.

107.5 When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.

107.5 In the lever, the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.

107.5 The distance of successive electron shells from the nucleus of an atom and from each other, are much greater than the dimensions of the nucleus itself.

107.5 Atoms have great subatomic energy.

Rank Order of Items for Questionnaire as a Whole (cont'd)

110 Elements may be changed into other elements.

111 Heat is conducted by the transfer of kinetic energy from molecule to molecule.

112.5 The properties of the elements show periodic variations with their atomic numbers.

112.5 The total change in length of a metal bar is equal to its coefficient of linear expansion times the original length times the change of temperature in degrees Centigrade.

114.5 The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of that force.

114.5 The colors of objects depend upon what light rays they transmit, absorb, or reflect.

116.5 The amount of momentum possessed by an object is proportional to its mass and to its velocity.

116.5 All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these constituents.

118.5 When two bodies of different temperature are in contact, there is a continuous transference of heat energy, the rate of which is directly proportional to the difference of temperature.

118.5 Non-metals comprise a group of elements whose atoms tend to gain or share electrons and whose compounds, when dissolved in polar solvents, are capable of forming negative ions.

120 Metals comprise a group of elements (other than hydrogen) whose atoms have a tendency to lose electrons readily and whose compounds when dissolved in polar solvents are capable of forming positive ions.

121.5 Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors.

121.5 Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation.

123 Some elements have more than one atomic weight due to differences

Rank Order of Items for Questionnaire as a Whole (cont'd)

in the neutron content of their nuclei.

124 A fluid has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement.

125 The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.

125 Metals may be arranged in an activity series according to their tendency to pass into ionic form by losing electrons.

128 The distance a body travels, starting from rest with a constant acceleration, is one-half the acceleration times the square of the time.

128 All rays passing through the centers of curvature of a mirror are reflected upon themselves.

128 Every pure liquid has its own specific boiling and freezing point.

130.5 The more nearly vertical the rays of radiant energy, the greater the number that will fall upon a given horizontal area, and the greater is the amount of energy that will be received by that area.

130.5 Harmonious musical intervals correspond to very simple frequency ratios.

132.5 Non-metals may be arranged in an activity series according to their tendency to pass into ionic form by gaining electrons.

132.5 The velocity of sound is directly proportional to the square root of the elasticity modulus and inversely proportional to the square root of the density of the transmitting medium.

134.5 The frequency of the vibration of a stretched string is inversely proportional to its length, diameter, and square root of its density; and directly proportional to the square root of the stretching force.

134.5 Luminous vapors and gases emit only certain kinds of light producing bright-line spectra.

Rank Order of Items for Questionnaire as a Whole (cont'd)

136 When white light passes through a substance that absorbs some waves and not others, certain bands of color are missing with the production of an absorption spectrum.

137 Every chemical element when heated to incandescence in a gaseous state has a characteristic glow and a characteristic spectrum which can be used to identify very small quantities of the element and which is related to the molecular and atomic structure of the gas.

141 In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.

141 Sliding friction is dependent upon the nature and coordination of the rubbing surfaces, proportional to the force pressing the surfaces together, and independent of area of contact.

141 Heat is transferred by convection, in currents of gases or liquids, the rate of transfer decreasing with an increase in the viscosity of the circulating fluid.

141 When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal.

141 When pressure is applied to any area of a liquid in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the liquid.

141 In a plane mirror a line running from any point on the object to the image of that point is perpendicular to the mirror.

141 Each element has its own characteristic X-ray spectrum.

147 An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed.

147 When light is incident upon a medium in which it will travel faster and when the angle of incidence is greater than the critical angle, it is totally reflected.

147 Centrifugal force is directly proportional to the square of the velocity, to the mass, and inversely proportional to the radius of rotations.

Rank Order of Items for Questionnaire as a Whole (cont'd)

147 When gas expands, heat energy is converted into mechanical energy.

147 Incandescent solids and liquids emit all wave lengths of light and give a continuous spectrum.

151 The energy which a body possesses on account of its motion is called kinetic energy and is proportional to its mass and the square of its velocity.

151 A pure chemical substance may be prepared from raw materials through utilization of their physical and chemical properties.

151 The pressure at a point in any fluid is the same in all directions.

153 Heat is liberated when a gas is compressed, and is absorbed when a gas expands.

154.5 The properties of alloys are dependent upon the relative amounts of their components, the extent of their compound formation, and upon the crystalline structure of the mixture.

154.5 The total mass of a quantity of matter is not altered by any chemical changes occurring among the materials composing it.

157.5 At any point on the earth's surface all bodies fall with a constant acceleration which is independent of the mass or size of the body if air resistance be neglected.

157.5 The exchange of the negative and positive ions of acids and bases results in the formation of water and a salt.

157.5 When parallel light strikes a concave spherical mirror, the rays, after reflection, pass directly through the principal focus only if the area of the mirror is small compared to its radius of curvature.

157.5 A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

161.5 A change in state of a substance from gas to liquid, liquid to solid, or vice versa, is usually accompanied by a change in volume.

161.5 The volume of an ideal gas varies inversely with the pressure upon it, providing the temperature remains constant.

Rank Order of Items for Questionnaire as a Whole (cont'd)

161.5 Acids and bases are substances which in water solution ionize to give hydrogen and hydroxyl ions, respectively, from their constituent elements.

161.5 As the velocity of flow through a constricted area increases, the pressure diminishes.

164 Movements of all bodies in the solar system are due to gravitational attraction and inertia.

167.5 Equal volumes of all gases under similar conditions of temperature and pressure contain very nearly the same number of molecules.

167.5 When a body which emits a bright line spectrum is moving toward or away from the observer, the lines are shifted toward the short or long wave length end of the spectrum respectively.

167.5 Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.

167.5 The amount of heat which a constant mass of liquid or solid acquires when its temperature rises a given amount is identical with the amount it gives off when its temperature falls by that amount.

167.5 If the same pressure is maintained, the volume of a gas is varied directly as the absolute temperature.

167.5 The distortion of an elastic body is proportional to the force applied provided the elastic limit is not exceeded.

171.5 The boiling point of any solution becomes lower as the pressure is decreased and higher as the pressure is increased.

171.5 The presence of a dissolved substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water.

173 The activity of an acid or base is proportional to the degree of ionization of the compound when in solution.

174 The period of a pendulum swinging through short arcs is independent of the weight of the bob but varies directly as the square root

Rank Order of Items for Questionnaire as a Whole (cont'd)

of the length and inversely as the square root of the acceleration of gravity.

175 All liquids are compressible but only to a slight degree.

176 If the volume of a confined body of gas is kept constant, the pressure is proportional to the absolute temperature.

178 The atmospheric pressure decreases with increasing water vapor content, other things being equal.

178 The higher the temperature of the air, the greater the amount of moisture required to saturate it.

178 The curvature of a wave front will be changed a given amount by a lens; namely 1/F.

181 Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn.

181 The heat of formation of any chemical compound equals its heat of decomposition.

181 Oxidation always involves the removal or sharing of electrons from the element oxidized, while the reduction always adds or shares with the element reduced.

183 The ingredients of a solution are homogeneously distributed through each other.

184 The pressure in a fluid in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as the depth and average density of the fluid.

185 Diffusible substances tend to scatter from the point of greatest concentration until all points are at equal concentration.

186 The speed of chemical reaction is increased by increasing the concentration of any of the reactants; and is decreased by decreasing the concentration of any of the reactants.

187 Any homogeneous body of liquid free to take its own position, will seek a position in which all exposed surfaces lie on the same horizontal plane.

Rank Order of Items for Questionnaire as a Whole (cont'd)

188.5 Colloidal particles may carry electrical charges.

188.5 Each combustible substance has a kindling temperature which varies with its condition, but may be greater or less than the kindling temperature of some other substance.

191 Freezing point depression and boiling point elevation are proportional to the concentration of the solution.

191 The rate of evaporation of a liquid varies with temperature, area of exposed surface, and saturation and circulation of the gas in contact with the liquid.

191 Gases may be converted into liquids by reducing the speed of their molecules.

193 The solubility of solutes is affected by heat, pressure, and the nature of the solute and solvent.

195 The rates of many reactions are affected by the presence of substances which do not enter into the completed chemical reaction.

195 Salts of strong acids and strong bases undergo negligible hydrolysis, while salts of inactive acids and inactive bases undergo more marked hydrolysis.

195 Bodies of land heat up and cool off more rapidly and more readily than bodies of water.

198.5 The dimensions of an image produced by a lens or a mirror are to the dimensions of the object as their respective distances from the lens or mirror are to each other.

198.5 The products of reacting substances may react with each other to form the original substances.

198.5 Oxidation and reduction occur simultaneously and are quantitatively equal.

198.5 The materials forming one or more substances, without ceasing to exist, may be changed into one or more new and measurably different substances.

201 If stress is applied to a reversible chemical system, there will be a readjustment in the system to relieve the stress.

Rank Order of Items for Questionnaire as a Whole (cont'd)

203 The rate of vaporization decreases with an increase of concentration of the vapor in the gas in contact with the liquid, the temperature remaining constant.

203 The sum of the reciprocals of the conjugate focal lengths of a lens or mirror equals the reciprocal of the principal focal length.

203 The specific heats of many elements are approximately inversely proportional to their atomic weights.

205.5 Fluids have no elastic limit for compression.

205.5 Equal amounts of heat raise equal numbers of atoms of all elements in the solid state through nearly equal intervals of temperature.

207.5 All chemical reactions which start with the same quantities of original substances, liberate the same amounts of energy in reaching a given final state, irrespective of the process by which the final state is reached.

207.5 In moving air, wind pressure increases as the square of the velocity.

209 When a mixture of gases is confined, each exerts its own pressure without reference to the pressure exerted by others.

210 Simple ionic reactions are typically rapid reactions.

211 When different amounts of one element are found in combination with a fixed weight of another element (in a series of compounds), the different weights of the first element are related to each other by ratios which may be expressed by small whole numbers.

212 Any substance soluble in two immiscible liquids will distribute itself between the two in proportion to its solubility in the two liquids.

214.5 Substances which expand upon solidifying have their melting points lowered by pressure; those which contract upon solidifying have their melting points raised by pressure.

214.5 The pressure of a saturated vapor is constant at a given temperature, and increases with an increase of temperature.

Rank Order of Items for Questionnaire as a Whole (cont'd)

214.5 The height to which a liquid rises in a capillary tube is directly proportional to the surface tension of the liquid and inversely proportional to the density of the liquid, and to the radius of the tube.

214.5 A beam of light may become plane polarized as the result of any circumstance which results in the suppression of one of the rectilinear components of the vibration without affecting the components at right angles to it.

218 The speed of diffusion of gases varies inversely with the square root of their densities.

218 In every sample of any compound substance formed, the proportion by weight of the constituent elements is always the same as long as the isotopic composition of each element is constant.

218 The solubility of a gas in an inert solvent varies directly with the pressure to which a gas is subjected.

221 Chemical reactions may be carried more nearly to completion by any condition that establishes an unusually low concentration of one of the products.

221 The gravimetric composition of a compound may be found by multiplying the atomic weights of the elements by their subscripts in the formula of the compound.

221 The atmosphere of the earth tends to prevent the heat of the earth's surface from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day.

223 When a chemical change takes place without the addition of heat from an external source, that substance which has the greatest heat of formation will tend to form.

225 A gas always tends to expand throughout the whole space available.

225 The free surface of a liquid contracts to the smallest possible area due to surface tension.

225 Reactions occurring at ordinary temperatures are predominantly exothermic.

Rank Order of Items for Questionnaire as a Whole (cont'd)

227 At a definite temperature and pressure, the relative combining volumes of gases and of gaseous products may be expressed approximately in small whole numbers.

228.5 If the vapor pressure of the water of hydration is greater than that of the moisture of the air, crystals will gradually yield up water to the air, and vice versa.

228.5 The principal cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressure to places of low atmospheric pressure to places of low atmospheric pressure.

230 A liquid will rise in a capillary tube if the contact angle between the liquid and the side of the tube is less than 90°, and will be depressed if the contact angle is greater than 90°.

231 The rate of osmosis is directly proportional to the difference in concentration on opposite side of the membrane.

232.5 Surface reactions predominate in all non-homogeneous reactions.

232.5 In the northern hemisphere great volumes of air revolve in a counter clockwise direction, and in the southern hemisphere, they revolve in a clockwise direction.

235 Temperature changes, pressure changes, the presence of electrolytes or the presence of oppositely charged particles may cause colloids to precipitate.

235 Colloids show greater chemical activity than the solid substances in mass, since rates of reaction are proportional to the surface area of the solid, other factors being equal.

235 In a saturated solution, the product of the molar concentrations of the ions is constant.

237 Suspended particles of colloids have a continuous, erratic movement due to colloidal, molecular, or ion impacts.

238 Whenever the product of the concentrations of any two ions in a

Rank Order of Items for Questionnaire as a Whole (cont'd)

mixture exceeds the value of the ion-product in a saturated solution of the compound formed by their union, this compound will be precipitated.

239.5 Colloids have the property of absorption to an unusual degree.

239.5 Whenever the product of the concentrations of any two ions in a mixture is less than the value of the ion-product in a saturated solution of the compound formed by their union, this compound, if present in the solid form, will be dissolved.